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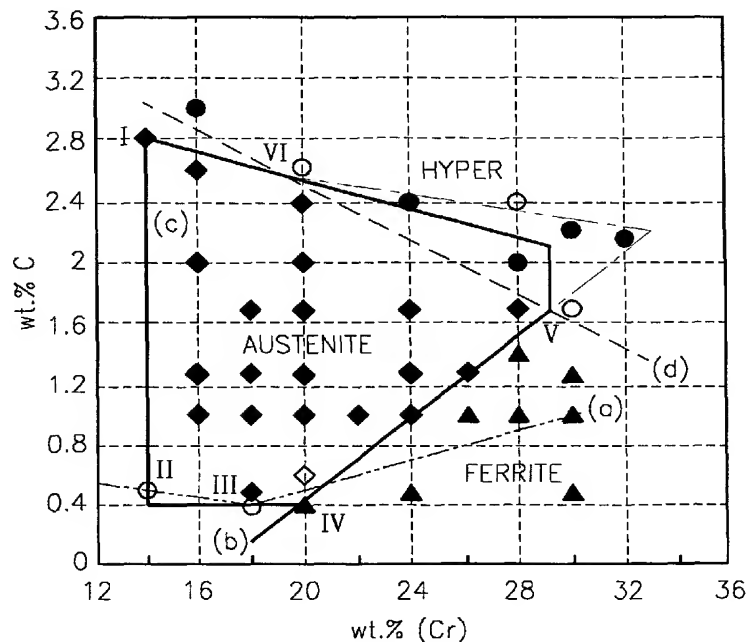
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(54) Title: FE-BASED HARDFACING ALLOY

(57) **Abstract:** An iron-based (Fe-based) hardfacing alloy is provided. The Fe-based hardfacing alloy has excellent wear resistance, excellent cavitation erosion resistance, and excellent corrosion resistance, thereby being substituted for a cobalt-based (Co-based) stellite alloy, which has been used for the hardfacing of a nuclear power plant valve. When the provided Fe-based hardfacing alloy is used for the hardfacing of the nuclear power plant valve, inexpensive Fe can be substituted for expensive Co and radiation fields formed by 58Co and 60Co radioactive io isotopes can be efficiently reduced.

Fe-BASED HARDFACING ALLOY

Technical Field

The present invention relates to a hardfacing alloy, and more particularly, to an iron-based (Fe-based) hardfacing alloy to be used in various industrial fields including the hardfacing of a nuclear power plant valve.

Background Art

In general, nuclear power plants operate for about one year and then plan pauses of about two to three months in order to replace nuclear fuel and examine and repair the nuclear power plants, more specifically, steam generator tubes. Here, if the steam generator tubes, which form the boundary of a primary system and a secondary system, are broken, radioactive primary system cooling water may flow out. Thus, the state of the steam generator tubes is examined by a non-destructive method and, when necessary, the steam generator tubes are repaired by performing plugging or sleeving. Such examination and repair are performed in a water box at a lower portion of the steam generator tube where radioactive materials are deposited, so nuclear power plant operators can be exposed to radioactive rays. The amount of radioactive exposure for the operators is proportional to the intensity of radiation field and the length of operating time in the radiation field. Accordingly, in order to lower the amount of radioactive exposure, the intensity of the radiation field and the length of the operating time in the radiation field have to be reduced.

Meanwhile, it is known that the radiation field of the primary system in the nuclear power plant is mainly formed by 58Co and 60Co radioactive isotopes, which are generated from worn and corroded

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cobalt-based (Co-based) stellite alloy as a hardfacing alloy of valves in the primary system.

Hardfacing as a method for overlaying a material having a high wear resistance on a contacting surface in order to increase the lifespan of a metal component reduces the number of parts that need to be repaired and pause periods for the repair and enables use of an inexpensive base material so that the cost for manufacturing the metal component is reduced. Here, the nuclear power plant valve is hardfacing treated because the nuclear power plant valve is used in a severe wear environment where temperature ranges from 90 to 343°C and a contact stress of 5 to 30 ksi are applied, so galling is likely to occur. Here, galling denotes severe damage on a surface and is likely to occur when metals are worn out under a high load and non-lubricant condition. Due to the galling, the surface roughness of the metal is significantly increased due to macro-plastic deformation on the worn surface. When the galling occurs on the nuclear power plant valve, a contacting surface becomes rough enough that leakage can occur, and the nuclear power plant valve may not operate entirely. Thus, galling of the nuclear power plant valve must be prevented.

The Co-based stellite alloy, which is used as a hardfacing alloy on the nuclear power plant valve, for example, stellite 6, is formed of 5 parts by weight of iron (Fe), 0.4 parts by weight of nickel (Ni), 1.1 parts by weight of carbon (C), 28 parts by weight of chromium (Cr), 2 parts by weight of manganese (Mn), 4 parts by weight of tungsten (W), and the remainder parts of Co. Hereafter, the stellite 6 will be referred to as the stellite alloy. The Co-based stellite alloy is widely used in high-temperature components where severe wear between metals occurs and in fields where a high corrosion resistance is required. However, as Co is a main source of the primary system radiation field, studies on developing a Co-free hardfacing alloy have been conducted.

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Studies on evaluating the performance of a Co-free hardfacing alloy has been conducted at Electric Power Research Institute (EPRI). Ni-based Deloro 50 alloy and Fe-based Norem alloy, which was developed by EPRI, showed relatively high wear resistances and have

5   been used in some nuclear power plant valves.   The Ni-based Deloro 50 alloy is formed of 4 parts by weight of Fe, 0.60 parts by weight of C, 13 parts by weight of Cr, 4 parts by weight of silicon (Si), and the remaining parts of Ni.   The Fe-based Norem alloy is formed of 1.25 parts by weight of C, 4.5 parts by weight of Mn, 25.0 parts by weight of

10 Cr, 3.3 parts by weight of Si, 4.0 parts by weight of Ni, 2.0 parts by weight of molybdenum (Mo), 0.16 parts by weight of nitrogen (N), and the remaining parts of Fe.

However, the wear resistances of the Ni-based Deloro 50 alloy and the Fe-based Norem alloy are examined under a limited condition.

15 Accordingly, it is difficult to determine whether the Ni-based Deloro 50 alloy and the Fe-based Norem alloy can be used in the nuclear power plant valve where a contact stress of 5 to 30 ksi is applied in a hot water having a temperature of 90 to 343°C.

In particular, it is known that the wear resistance of the Ni-based

20 Deloro 50 alloy largely depends on temperature than on contact stress, and the wear resistance of the Ni-based Deloro 50 alloy is significantly lowered when a high contact stress of 30 ksi is applied at a temperature of lower than 200 to 250°C where oxidative wear occurs.   In addition, the wear resistance of the Fe-based Norem alloy is excellent when a

25 contact stress of 15 ksi is applied up to a temperature of 180°C; however, the wear resistance is suddenly lowered at a temperature higher than 190°C.   In particular, the wear resistance of the Fe-based Norem alloy is significantly lowered at a temperature of 120°C when a high contact stress of 30 ksi is applied.

30 As described above, the wear resistances of the Ni-based Deloro

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50 alloy and the Fe-based Norem alloy are significantly lowered at a low temperature of less than about 200°C and at a high temperature of above about 190°C, respectively. Accordingly, a new hardfacing alloy must be developed in order to maintain excellent wear resistance under the operation conditions of a nuclear power plant valve, which are a temperature of 90 to 343°C and a contact stress of 5 to 30 ksi.

Disclosure of the Invention

To solve the above-described problems, the present invention provides a hardfacing alloy that can prevent the problems of a cobalt-based (Co-based) stellite alloy, which generates radioactive rays due to radioactive isotopes in the hardfacing treatment of a nuclear power plant valve, while having excellent wear resistance, cavitation erosion resistance, and corrosion resistance.

According to one aspect of the present invention, there is provided a hardfacing alloy formed of 14 to 30 parts by weight of chromium (Cr), 0.4 to 2.8 parts by weight of carbon (C), which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of silicon (Si), and the remaining parts of iron (Fe). In particular, the hardfacing alloy is formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, and the remaining parts of Fe.

According to another aspect of the present invention, there is provided a hardfacing alloy for a nuclear power plant valve, the hardfacing alloy formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, and the remaining parts of Fe. In particular, the hardfacing alloy is formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, and the remaining parts of Fe.

According to still another aspect of the present invention, there is provided a hardfacing alloy formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, 1 to 2 parts by
5   weight of cerium (Ce), and the remaining parts of Fe. In particular, the hardfacing alloy is formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe.

According to yet still another aspect of the present invention,
10   there is provided a hardfacing alloy for a nuclear power plant valve, the hardfacing alloy formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe. In particular, the hardfacing alloy is
15   formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe.

When the Fe-based hardfacing alloy is used in the hardfacing of the nuclear power plant valve, Co as a source of the radiation field is
20   removed, so the amount of radioactive rays is reduced by about 35%. In addition, the Fe-based hardfacing alloy according to the present invention has excellent wear resistance, cavitation erosion resistance, and corrosion resistance, so the Fe-based hardfacing alloy can be used in industrial fields, in devices such as an impeller, a turbine blade, and a
25   valve of a pump.

Brief Description of the Drawings

FIG. 1 illustrates the state of a Fe-based hardfacing alloy according to the present invention;

30   FIG. 2 is a graph illustrating the wear losses of hardfacing alloys

of prior art and the present invention, according to temperature;

FIG. 3 is a graph illustrating the wear losses of hardfacing alloys of prior art and the present invention, according to cycle;

FIGS. 4A through 4G are graphs illustrating the friction coefficients of hardfacing alloys of prior art and the present invention, according to sliding time;

FIGS. 5A through 5G are optical microscopy photographs of hardfacing alloys of prior art and the present invention, taken after the hardfacing alloys are worn;

FIG. 6 is a graph illustrating the cavitation erosion resistances of hardfacing alloys of prior art and the present invention;

FIGS. 7A through 7H are optical microscopy photographs of hardfacing alloys of prior art and the present invention, taken after cavitation erosion is performed on the hardfacing alloys at a normal temperature for 10 hours;

FIGS. 8A through 8D are photographs of the surfaces of hardfacing alloys according to the present invention and general hardfacing alloys after corrosion; and

FIG. 9 is a graph illustrating the polarization results of hardfacing alloys of prior art and the present invention.

Best mode for carrying out the Invention

The present invention will now be described in more detail with reference to the accompanying drawing, in which preferred embodiments of the invention are shown.

When an iron-based (Fe-based) alloy receives stress, a strain-induced martensite transformation occurs, and two types of martensite, such as α' and ε, are formed. In the case of $v \rightarrow \alpha'$ strain-induced martensite transformation, shear bands, such as stacking fault and twin, have to be formed or crossed, and the crossed portions

have to be perform as the embryo of the α' martensite. On the other hand, in the case of $\nu \to \varepsilon$ strain-induced martensite transformation, the trace of a Shockley partial dislocation becomes the ε martensite. Here, such martensite phases harden the surfaces of alloys, so the

5   alloys attain excellent wear resistance. Therefore, it is assumed that the Fe-based hardfacing alloy presents excellent wear resistance at a low temperature because of a large amount of carbide disperse phase and a low level of stacking defective energy of a matrix phase, in particular, a high work hardening rate by the strain-induced martensite

10   transformation. When a maximum temperature, i.e., Md temperature, for incurring the strain-induced martensite transformation is increased to higher than 343°C, which is the operation temperature of a nuclear power plant valve, it is assumed that a high eutectic rate of cure is maintained at the high temperature so that excellent wear resistance will

15   be attained. To this end, a Fe-based hardfacing alloy had been invented by selecting an austenite region, which has the Md temperature of about 450°C and can generate the strain induced martensite transformation. In this case, a relatively small amount of hard disperse phase is included so that the hardfacing process can be easily

20   performed. Therefore, such a method is determined to be the most efficient method for improving the wear resistance of the Fe-based hardfacing alloy at a high temperature.

FIG. 1 illustrates the state of a Fe-based hardfacing alloy according to the present invention.

25   More specifically, FIG. 1 illustrates the phase forming behavior for the different concentrations of chromium (Cr) and carbon (C) in the Fe-based hardfacing alloy. In general, when the amounts of Cr and C are varied, a region where an austenite phase is stable is represented as a Schaeffler diagram, which is denoted by (a). In other words, a

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portion above the line denoted by (a) is a region where the austenite phase is stable. However, according to the present invention, when Cr and C are added to the amount represented by a portion to the right of line (b), i.e., a portion represented by ▲, the formation of the austenite

5   phase is restricted and ferrite is generated. This is because the amount of carbide is increased according to the increase in the amounts of Cr and C. In addition, a region within lines (b) and (c) is where shrinkage does not severely occur.

When the concentration of Cr and C exceeds a eutectic point,

10   hypereutectic structures are formed, as illustrated by ●. Since the eutectic structures of the austenite phase and carbide are formed after primary solid phase carbide is formed in the hypereutectic structures, the hypereutectic structures have disadvantages of having a large amount of carbide, showing coarse microstructures, showing a large difference

15   between the microstructures due to different cooling speeds, and lowering weldability. In particular, when the concentration of C is insufficient in the hypereutectic structure, the concentration of C in the matrix phase may be exhausted and the ferrite may form. In this case, such ferrite phase has a lower eutectic rate of cure than that of the

20   austenite phase, and a strain induced martensite transformation does not occur in the ferrite phase. In addition, plastic deformation can easily occur in the ferrite phase, so the ferrite phase can be severely worn in a high load wear environment. Therefore, a hypoeutectic austenite alloy would be proper to form the Fe-based hardfacing alloy

25   having excellent weldability and excellent wear resistance by the strain-induced martensite transformation. In FIG. 1, the portion where the hypoeutectic austenite alloy is formed is located at the lower side of line (d), i.e., a portion represented by ◆.

As a result, the composition range of the Fe-based hardfacing

30   alloy according to the present invention, which has excellent wear

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resistance in an environment where a contact stress of 5 to 30 ksi is applied in a hot water having a temperature of 90 to 343°C, is represented by ♦. Here, the composition range has 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of silicon (Si), and the remaining parts of Fe. In this case, less than 1.5 parts by weight of Si is added to the alloy in order to improve the dispersion of solder when performing overlay for hardfacing. In addition, the above-described Fe-based hardfacing alloy has an excellent cavitation erosion resistance as will be described later.

When 1 to 2 parts by weight of cerium (Ce) is added to the above-described Fe-based hardfacing alloy, the Fe-based hardfacing alloy has excellent cavitation erosion resistance and corrosion resistance as well as wear resistance. In other words, the Fe-based hardfacing alloy having excellent wear resistance, cavitation erosion resistance, and corrosion resistance is formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe.

Hereafter, the wear resistances, the cavitation erosion resistances, and the corrosion resistances between the hardfacing alloy according to the present invention and the conventional hardfacing alloy used in the hardfacing of the nuclear power plant valve will be compared.

More specifically, the Fe-based hardfacing alloy according to an embodiment of the present invention is formed of 20 parts by weight of Cr, 1.3 or 1.7 parts by weight of C, 1 part by weight of Si, and the remaining parts of Fe. Hereafter, the Fe-based hardfacing alloy including 1.3 parts by weight of C will be referred to as 1.3C and the Fe-based hardfacing alloy including 1.7 parts by weight of C will be referred to as 1.7C.

In addition, the Fe-based hardfacing alloy according to another embodiment of the present invention is formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of

5   Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe. Hereafter, the Fe-based hardfacing alloy including 1 part by weight of Ce will be referred to as AT-NC1, and the Fe-based hardfacing alloy including 2 parts by weight of Ce will be referred to as AT-NC2.

FIG. 2 is a graph illustrating the wear losses of the hardfacing

10   alloys of prior art and the present invention, according to temperature.

More specifically, FIG. 2 is a graph illustrating the result of a sliding wear experiment for 100 cycles while varying temperature in order to evaluate the wear characteristics of the hardfacing alloys. In the case of the Norem alloy, galling occurs at a temperature of higher

15   than 190°C, which is the temperature when strain-induced martensite transformation starts, and so the Norem alloy is improper for use as a hardfacing alloy for a nuclear power plant valve.

On the other hand, the 1.7C as the hardfacing alloy according to the present invention presents a better wear resistance than the stellite

20   alloy, at a temperature range from a room temperature to 450°C. The 1.3C as the hardfacing alloy according to the present invention represents wear resistance similar to that of the stellite alloy until the temperature is increased to 350°C. The AT-NC1 as the hardfacing alloy according to the present invention presents wear resistance similar

25   to that of the stellite alloy at a temperature range from a room temperature to 400°C.

FIG. 3 is a graph illustrating the wear losses of the hardfacing alloys of prior art and the present invention, according to cycle.

More specifically, the X-axis represents the number of wear

30   cycles, and the Y-axis represents the wear loss. As shown in FIG. 3,

the 1.7C and the AT-NC1 as the hardfacing alloys according to the present invention present wear losses less than that of the conventional stellite alloy, even if the cycle is increased. Therefore, the 1.7C and the AT-NC1 are determined to have excellent wear resistances.

FIGS. 4A through 4G are graphs illustrating the friction coefficients of the hardfacing alloys of prior art and the present invention, according to sliding time.

More specifically, FIGS. 4A and 4B illustrate the measurement results of the stellite alloy and the Norem alloy, respectively, at a temperature of 450°C and a contact stress of 15 ksi. FIGS. 4C and 4D illustrate the measurement results of the 1.7C as the hardfacing alloy according to the present invention at temperatures of 300°C and 450°C and a contact stress of 15 ksi, respectively. FIGS. 4E and 4F illustrate the measurement results of the 1.3C as the hardfacing alloy according to the present invention at temperatures of 250°C and 450°C and a contact stress of 15 ksi, respectively. FIG. 4G illustrates the measurement result of the AT-NC1 as the hardfacing alloy according to the present invention at a temperature of 400°C and a contact stress of 15 ksi.

In general, since a valve driven by a motor can be worn down as a result of an increase in the friction coefficient, the hardfacing alloy for a nuclear power plant valve is required to have a friction coefficient below a predetermined value. As shown in FIG. 4B, the Norem alloy presents a high momentary friction coefficient of higher than 1.0 due to severe wear and unevenness on the surface and presents a high friction coefficient of over 4.0 even at a normal temperature. However, the 1.7C, the 1.3C, and the AT-NC1 as the hardfacing alloys according to the present invention present friction coefficients of less than 1.0, which is similar to that of the stellite alloy of FIG. 4A.

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FIGS. 5A through 5G are optical microscopy photographs of the hardfacing alloys of prior art and the present invention, taken after the hardfacing alloys have been worn down.

More specifically, FIGS. 5A through 5C are optical microscopy photographs of the surfaces of the 1.7C, the Norem alloy, and the stellite alloy, respectively, after being worn down at a normal temperature, i.e., 25°C, for 1000 cycles. FIGS. 5D through 5G are optical microscopy photographs of the surfaces of the 1.7C, the Norem alloy, the stellite alloy, and the AT-NC1, respectively, after being worn at a temperature of 300°C for 1000 cycles.

The surfaces of the 1.7C and the AT-NC1 of FIGS. 5A, 5D, and 5G and the stellite alloy of FIGS. 5C and 5F are smooth regardless of the experimental conditions; however, the surfaces of the Norem alloy of FIGS. 5B and 5E are rough due to galling after being worn at the temperature of 300°C.

Next, air bubbles are generated and eliminated around the nuclear power plant valve due to the difference in the moving speeds of fluid. Here, a pressure generated in the elimination of the bubbles damages the surface of the nuclear power plant valve. In order to detect such a cavitation erosion, an experiment is performed where air bubbles are formed on the surface of a material by using supersonic waves at a normal temperature for 50 hours and damages on the surface of the material are checked for.

FIG. 6 is a graph illustrating the cavitation erosion resistances of the hardfacing alloys of prior art and the present invention.

More specifically, the Norem alloy presents a loss amount, i.e., a cavitation erosion amount, of six times as much as that of the stellite alloy. However, the 1.7C and the At-NC2 as the Fe-based hardfacing alloys according to the present invention present much smaller loss amounts than that of the stellite alloy. As a result, the Fe-based

hardfacing alloy according to the present invention is determined to have excellent cavitation erosion resistance.

FIGS. 7A through 7H are optical microscopy photographs of the hardfacing alloys of prior art and the present invention, taken after the

5   cavitation erosion takes place on the hardfacing alloys at a normal temperature for 10 hours.

More specifically, FIGS. 7A and 7B are optical microscopy photographs of the conventional stellite alloy taken after cavitation erosion takes place. As shown in FIGS. 7A and 7B, cracks occurred at

10   the boundaries between the matrix phase and the deposit, which are the weakest portions, and the deposit eroded away. FIGS. 7C and 7D are optical microscopy photographs of the conventional Norem alloy taken after the cavitation erosion takes place. As shown in FIGS. 7C and 7D, the cavitation erosion took place on the Norem alloy, and the Norem

15   alloy is severely damaged to the degree that the deposit cannot be distinguished from the matrix phase.

FIGS. 7E and 7F and FIGS. 7G and 7H are optical microscopy photographs of the 1.7C and the AT-NC1, respectively, as the hardfacing alloys according to the present invention, after the cavitation

20   erosion has occurred. As shown in FIGS. 7E and 7H, unlike the stellite alloy and the Norem alloy, the hardfacing alloy according to the present invention does not have cracks between the carbide and the matrix phase. As a result, the hardfacing alloy according to the present invention has the same or better cavitation erosion resistance and as the

25   wear resistance as these of the stellite alloy. In addition, the hardfacing alloy according to the present invention has much better characteristics than the Fe-based Norem alloy.

Next, the hardfacing alloys of prior art and the present invention are corroded for seven days in a pressurized container filled with water

30   at a temperature of 300°C in order to evaluate the corrosion resistances

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of the alloys.   The experimental results are shown in Table 1 and FIGS.
8A through 8D.   Here, FIGS. 8A and 8B are photographs of the
surfaces of the AT-NC1 and the AT-NC2 as the hardfacing alloy
according to the present invention, after corrosion.   FIGS. 8C and 8D
are photographs of the surfaces of conventional SUS 304 alloy and SUS
409 alloy after corrosion.

Table 1

day kind		0	1	3	7
Norem	Gravity change	1.4600	1.4598	1.4598	1.4598
	Surface color	silver white	brindle	dark	red
	Degree of rusting	-	-	light	heavy
Stellite	Gravity change	0.7010	1.7008	0.7008	0.7007
	Surface color	silver white	light yellow	light yellow	light yellow
	Degree of rusting	-	-	-	-
AT-NC1	Gravity change	1.4862	1.4863	1.5378	1.5379
	Surface color	silver white	pitting	pitting	gray
	Degree of rusting	-	-	-	heavy
AT-NC2	Gravity change	1.4862	1.4863	1.4869	1.4864
	Surface color	silver white	yellow	yellow	blue purple
	Degree of rusting	-	-	-	light
SUS 304	Gravity change	2.0206	2.0206	2.0208	2.0208
	Surface color	silver white	yellow	yellow	blue yellow
	Degree of rusting	-	-	-	light
SUS 409	Gravity change	1.1870	1.1869	1.1870	1.1873
	Surface color	silver white	brindle	brindle	gray

	Degree of rusting	-	-	-	heavy

According to Table 1, it is difficult to detect significant changes in the specific gravities of the alloys in order to evaluate the corrosion resistances of the alloys, because the sizes of the specimens are small. However, the corroded state of the surface of the AT-NC2 as the hardfacing alloy according to the present invention shown in FIG. 8B is the same as the corroded state of the surface of the SUS 304.

FIG. 9 is a graph illustrating the polarization results of the hardfacing alloys of prior art and present invention.

More specifically, the polarization experiment of FIG. 9 is performed under the conditions of a scan speed of 3mV/sec and a NaOH solution of 10 % and having a temperature of 25°C. As shown in FIG. 9, a secondary passive film is formed on the AT-NC2 as the Fe-based hardfacing alloy according to the present invention as well as on the stellite alloy, and so it is assumed that the AT-NC2 will present excellent corrosion resistance.

As described above, when the Fe-based hardfacing alloy according to the present invention is used in the hardfacing of the nuclear power plant valve, Co as the source of the radiation field is removed, so the amount of the radioactive rays can be reduced by about 35 %.

When the Fe-based hardfacing alloy according to the present invention is used in the hardfacing of the nuclear power plant valve, the amount of the radioactive rays the operators of the nuclear power plant are exposed to is reduced, and the safety of the operators is improved. In addition, the efficiency of the operation of the nuclear power plant is improved, and the cost for operating the nuclear power plant is reduced by shortening the amount of time required in treating the nuclear power

plant valve. Furthermore, the disposal cost of radioactive waste is reduced, and the reliability of the safety of the nuclear power plant is improved due to the low level radioactive wastes.

5   The Fe-based hardfacing alloy according to the present invention has the same levels of wear resistance, cavitation erosion resistance, and corrosion resistance as those of the stellite alloy, which is generally used in the hardfacing of the nuclear power plant valve. Accordingly, the Fe-based hardfacing alloy according to the present invention can be substituted for the stellite alloy. In this case, expensive Co is not used,

10 so the leakage of radioactive rays is reduced, and the cost for the hardfacing is reduced.

In addition, the Fe-based hardfacing alloy according to the present invention can increase the lifespan of components such as impellers, turbine blades, and valves of pumps, which are widely used in

15 industrial fields and easily damaged by wear and corrosion, by simple welding operations. Therefore, the efficiency of a machine is significantly improved, and the cost for maintaining the machine is reduced.

The drawings and specification of the invention are provided for

20 illustration only and are not used to limit the scope of the invention set forth in the appended claims.

Industrial Applicability

As described above, an iron-based (Fe-based) hardfacing alloy

25 according to the present invention can be used in components such as impellers, turbine blades, and valves of pumps, which are widely used in industrial fields and easily broken by wear and corrosion.

What is claimed is:

1.   A hardfacing alloy formed of 14 to 30 parts by weight of chromium (Cr), 0.4 to 2.8 parts by weight of carbon (C), which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of silicon (Si), and the remaining parts of iron (Fe).

2.   The hardfacing alloy of FIG 1, formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, and the remaining parts of Fe.

3.   A hardfacing alloy for a nuclear power plant valve, the hardfacing alloy formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, and the remaining parts of Fe.

4.   The hardfacing alloy of FIG. 3, formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, and the remaining parts of Fe.

5.   A hardfacing alloy formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, 1 to 2 parts by weight of cerium (Ce), and the remaining parts of Fe.

6.   The hardfacing alloy of FIG. 5, formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe.

7.   A hardfacing alloy for a nuclear power plant valve, the

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hardfacing alloy formed of 14 to 30 parts by weight of Cr, 0.4 to 2.8 parts by weight of C, which are illustrated as a portion formed by points I-VI-I of FIG. 1, less than 1.5 parts by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe.

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8.   The hardfacing alloy of FIG. 7, formed of 20 parts by weight of Cr, 1.7 or 1.3 parts by weight of C, 1 part by weight of Si, 1 to 2 parts by weight of Ce, and the remaining parts of Fe.

FIG. 1
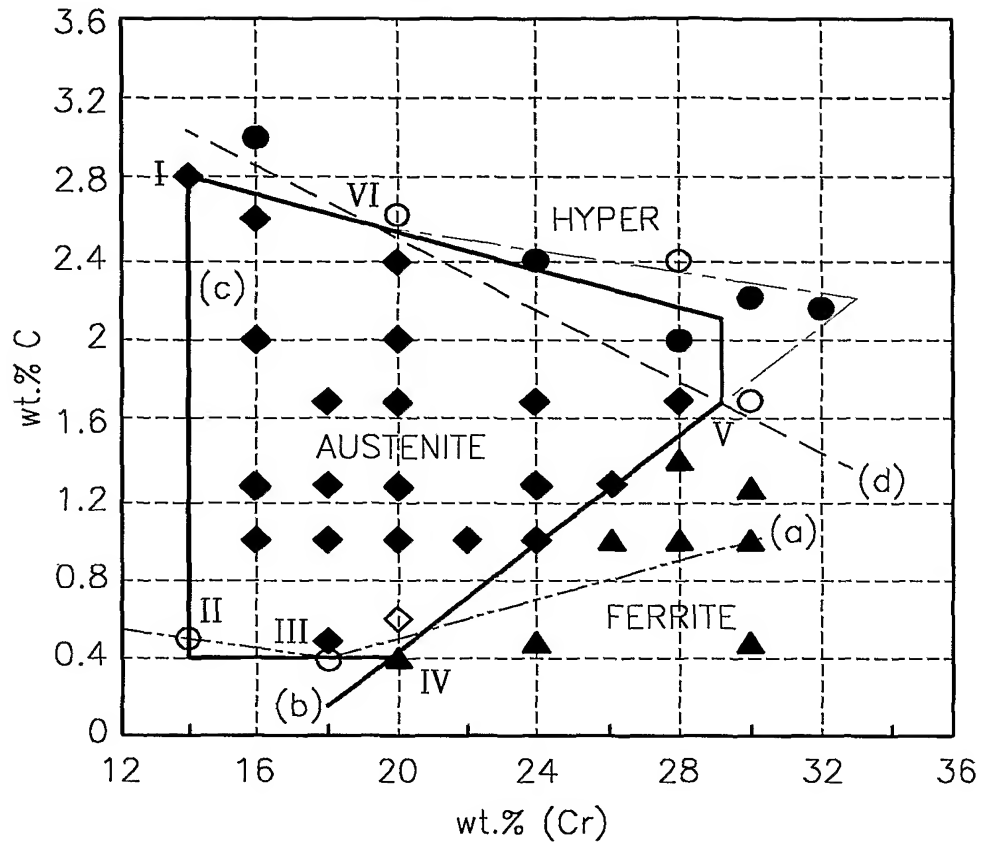
FIG. 2

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FIG. 3

FIG. 4A
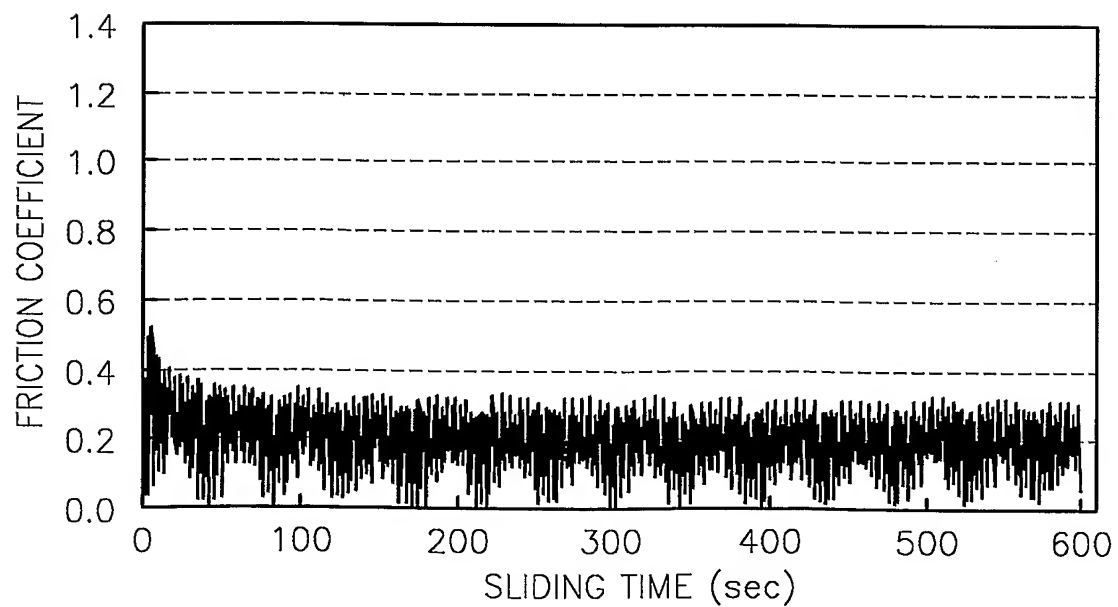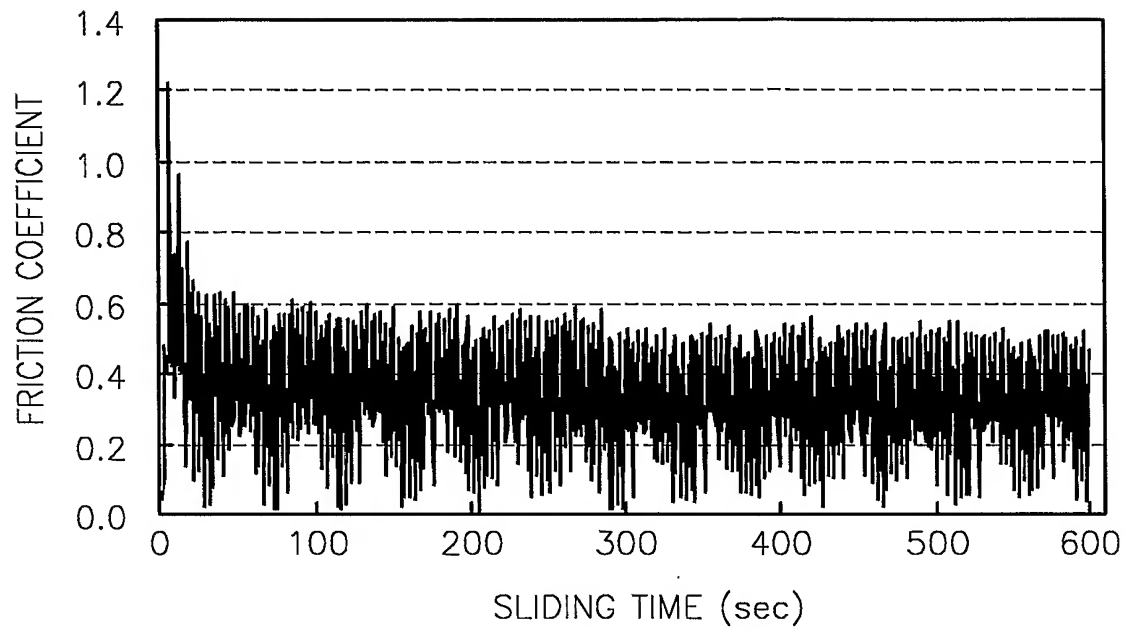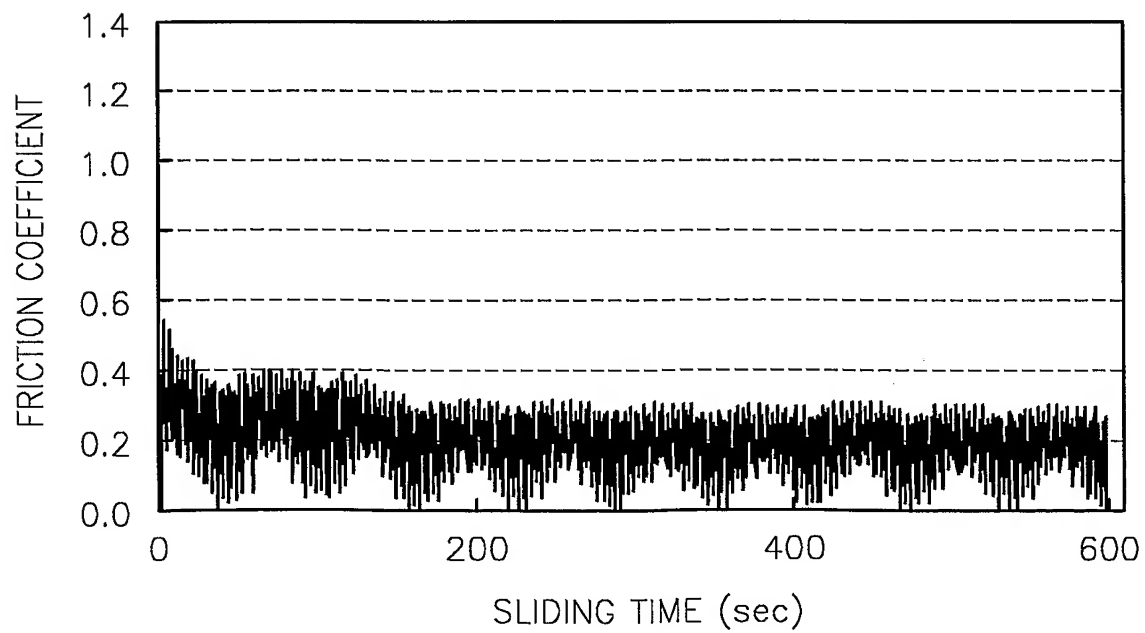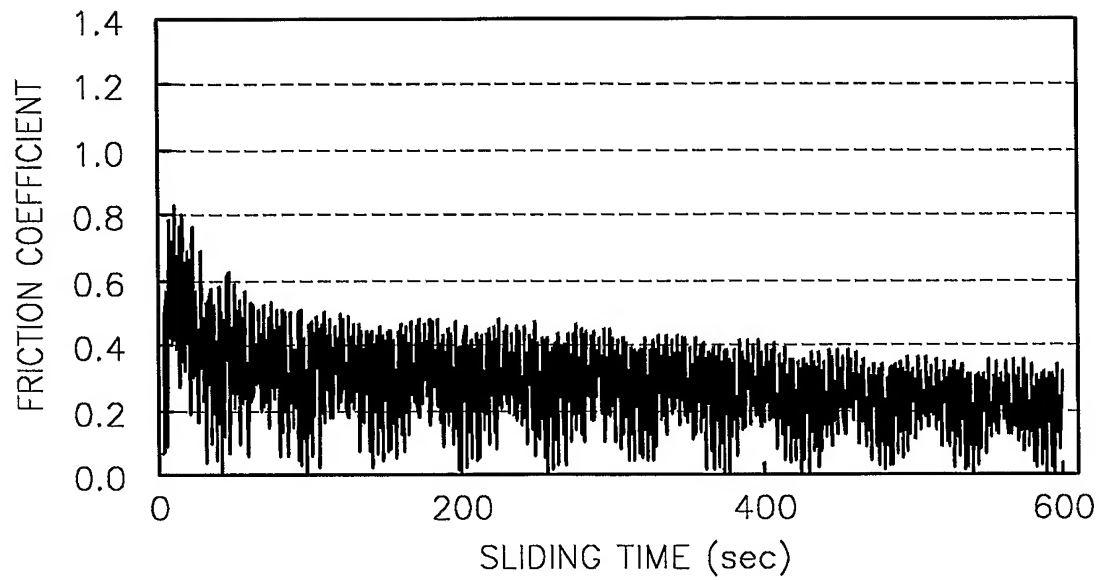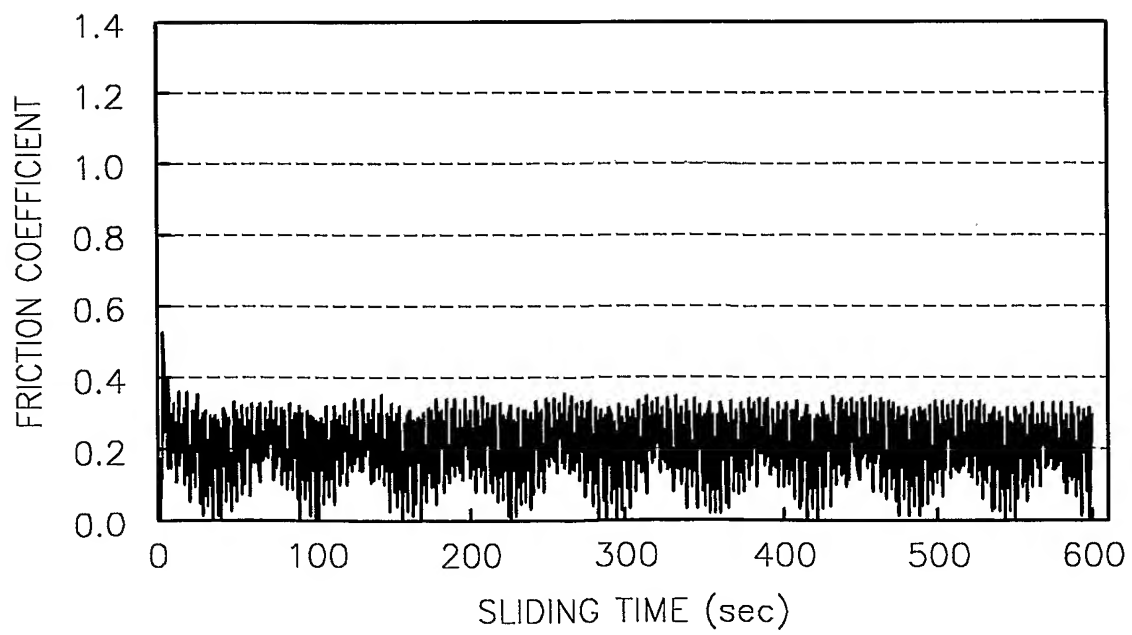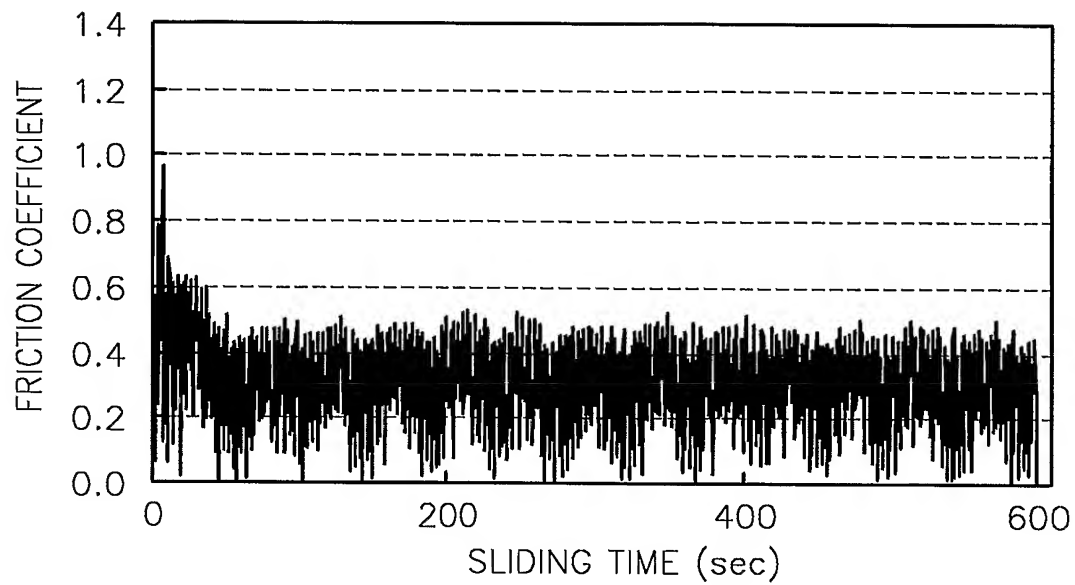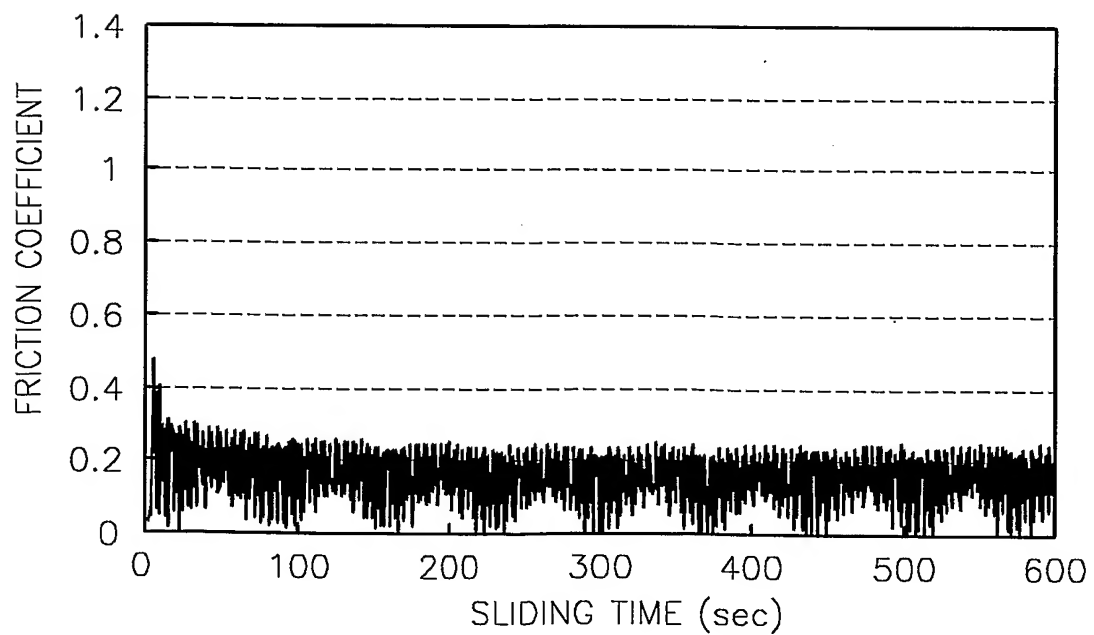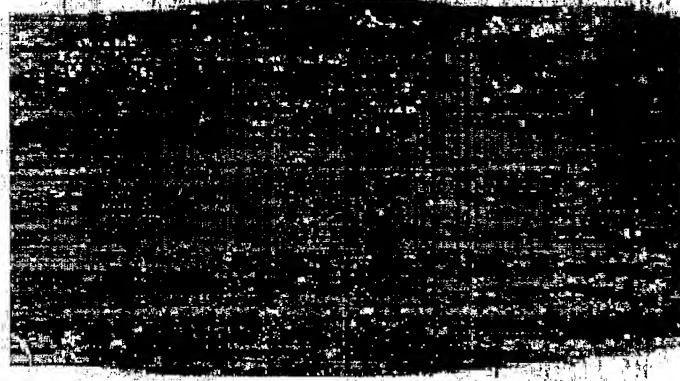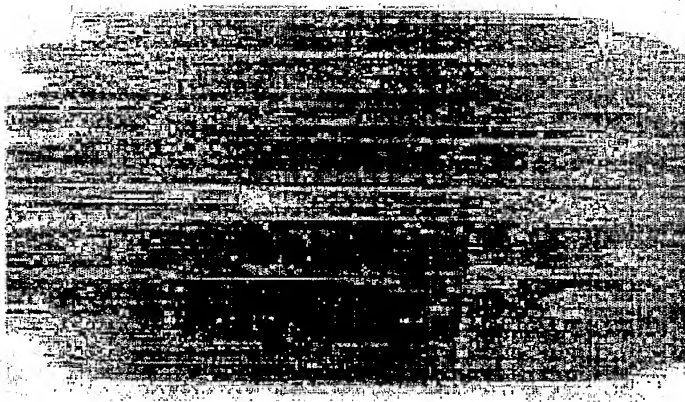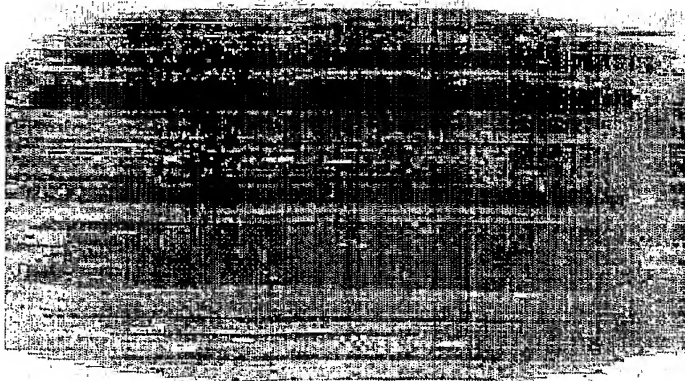
FIG. 4B

FIG. 4C

FIG. 4D

FIG. 4E

FIG. 4F

FIG. 4G

FIG. 5A

FIG. 5B

FIG. 5C

FIG.5D

FIG. 5E

FIG. 5F

FIG. 5G

FIG. 6

FIG. 7A

100 μm

FIG. 7B

30 μm

FIG. 7C

100 μm

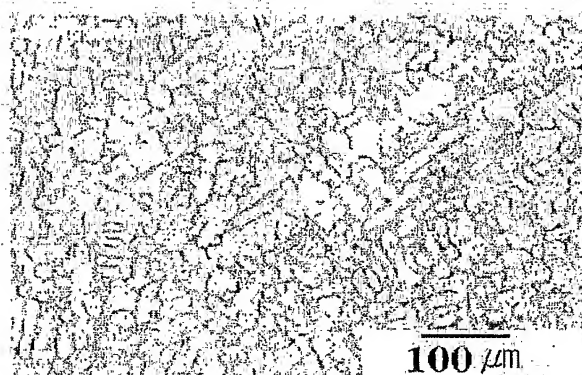## FIG. 7D
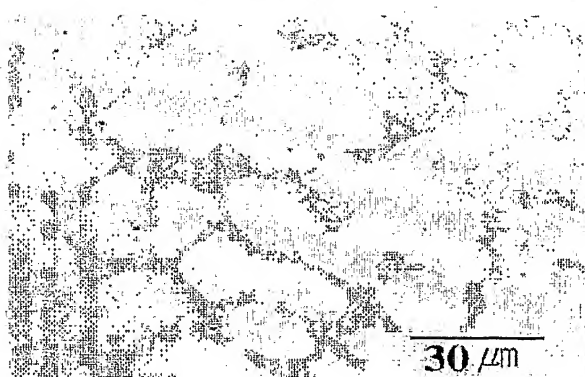

30 μm

FIG. 7E

100 μm

FIG. 7F

30 μm

FIG. 7G

100 μm

FIG. 7H

30 μm
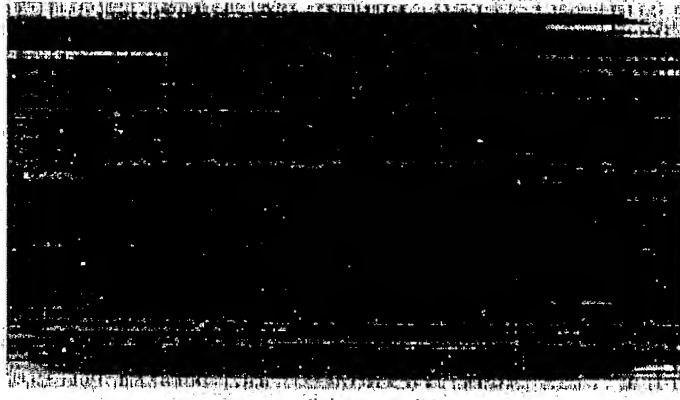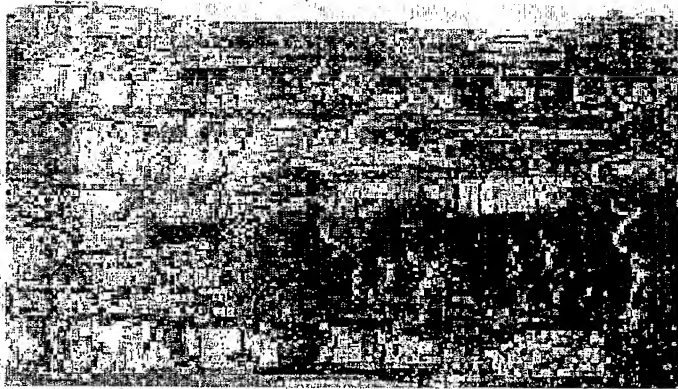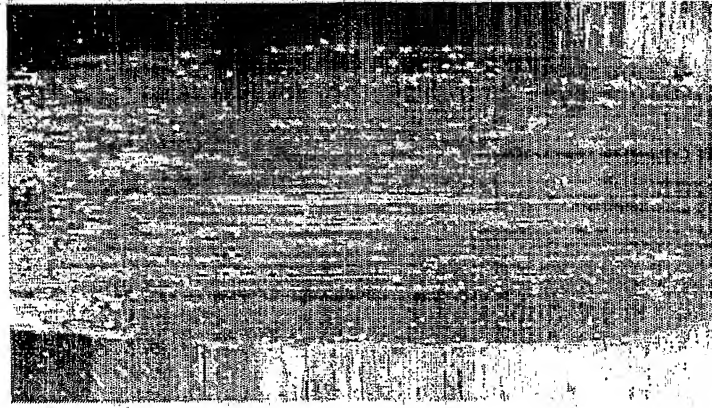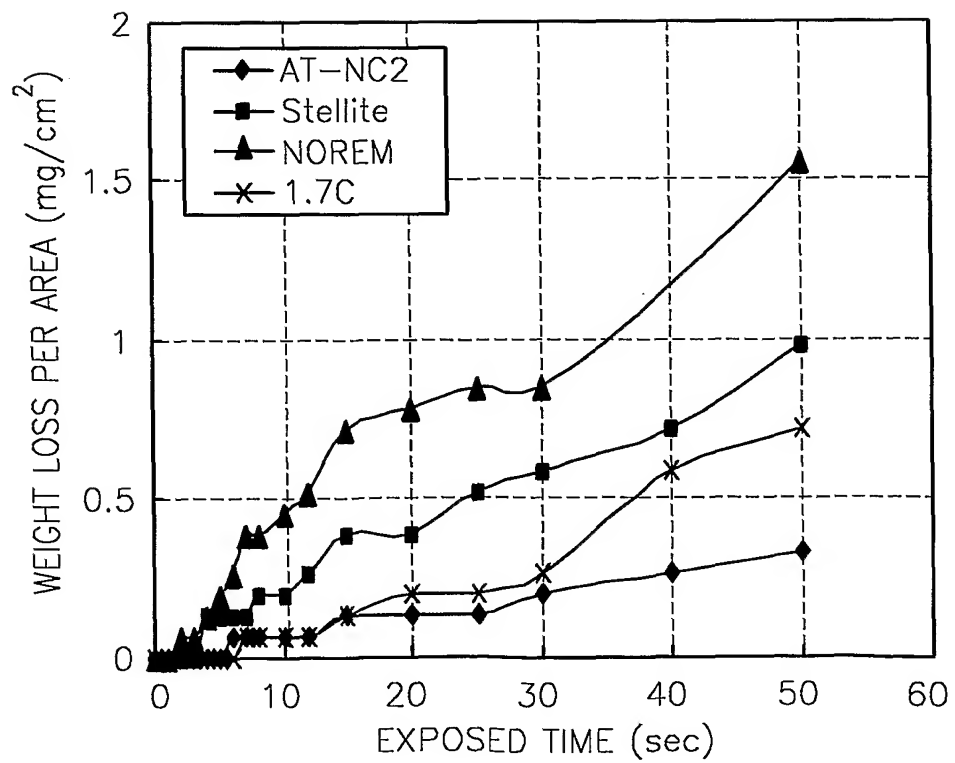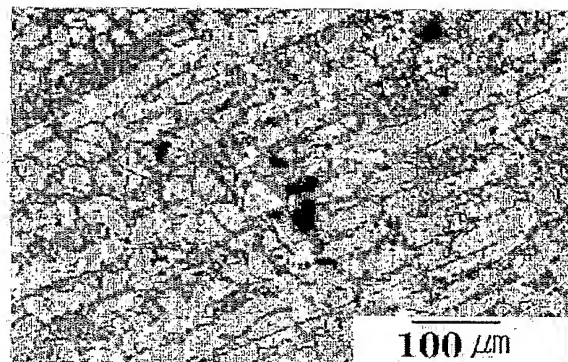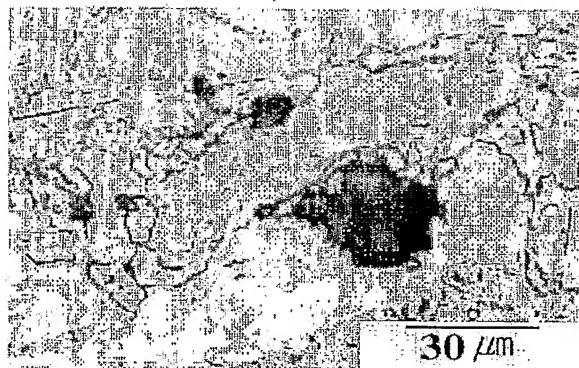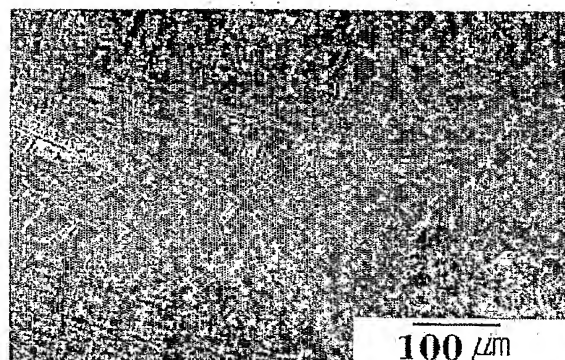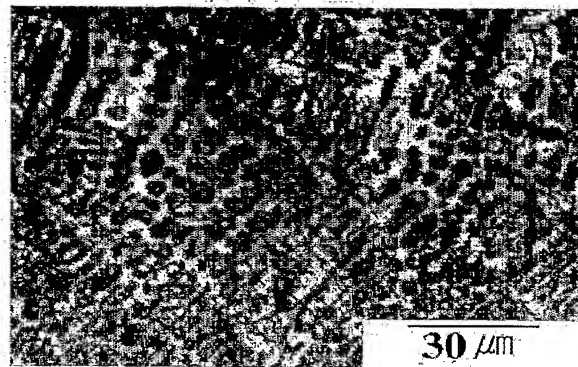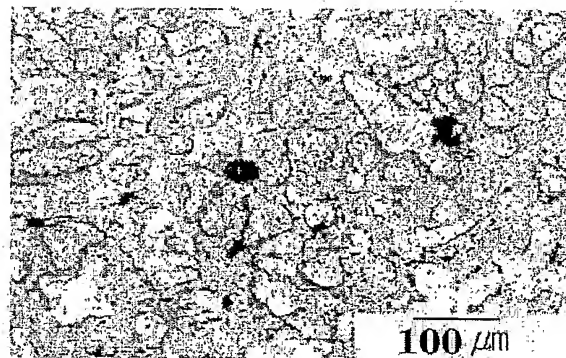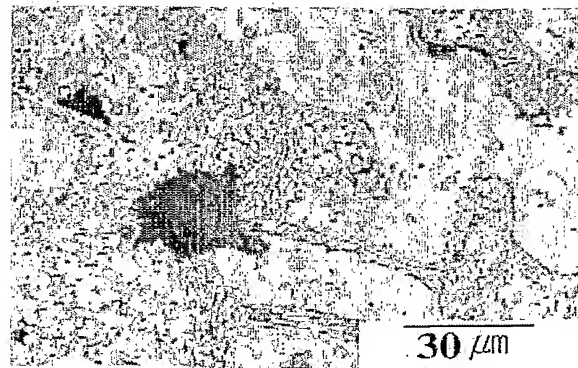
FIG. 8A
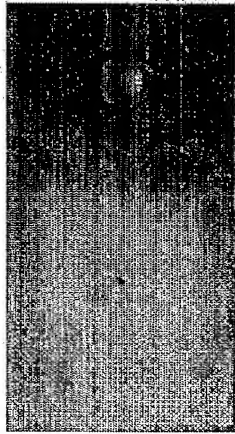
FIG. 8B
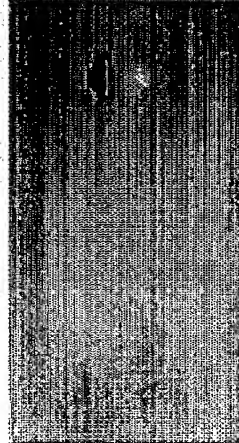
FIG. 8C
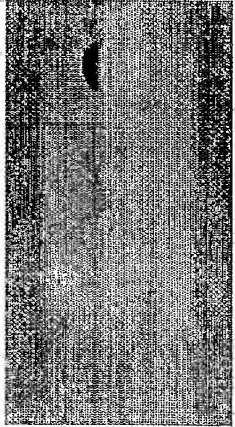
FIG. 8D
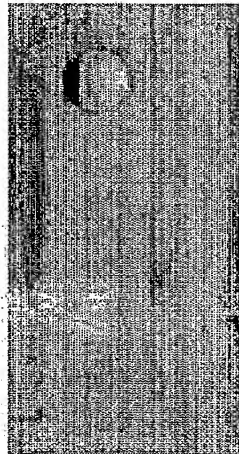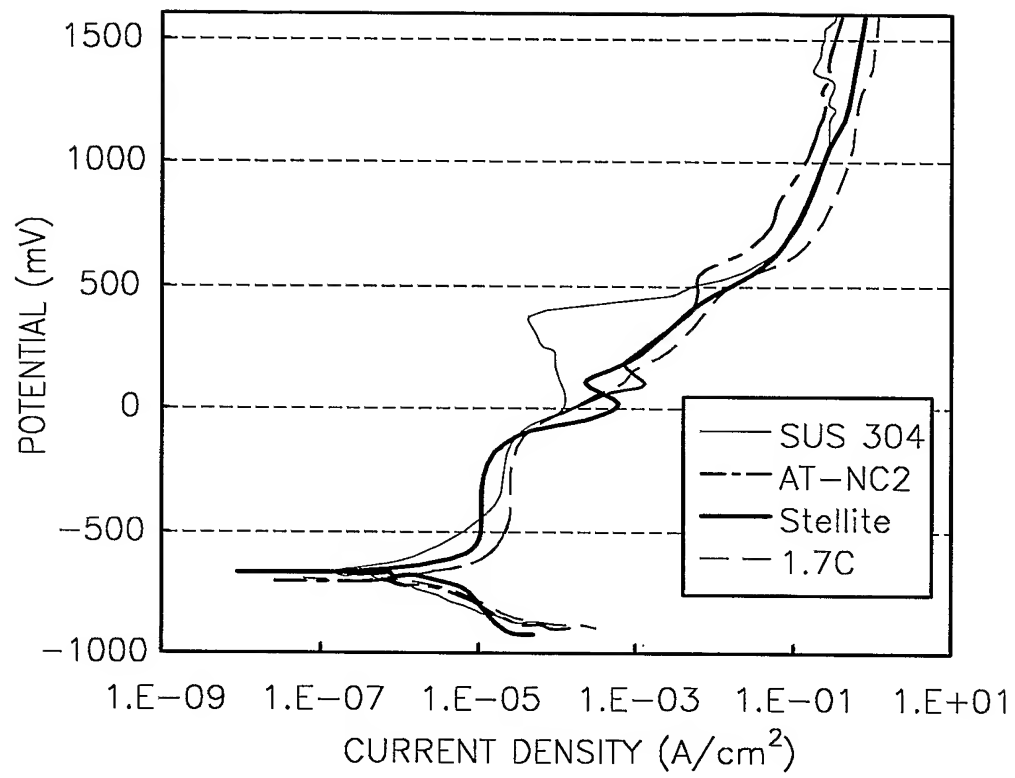
FIG. 9

INTERNATIONAL SEARCH REPORT

A.	CLASSIFICATION OF SUBJECT MATTER

IPC7 C22C 38/18

According to International Patent Classification (IPC) or to both national classification and IPC

B.	FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7. C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Patents and applications for inventions since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)
New Patent & Utility Search System(KIPO)

C.	DOCUMENTS CONSIDERED TO BE RELEVANT	.

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E,X	KR 2002-0076945 A(Hanyang Hak Won Co.,Ltd) 11 October 2002 See claims 1 ~ 4	1 ~ 4
A	KR 2002-0014853 A(Doosan Heavy Industries & Construction Co.,Ltd) 27 February 2002 See the whole document	1 ~ 8
A	JP 7-18365 A(Mitsubishi Heavy Ind Ltd.) 20 January 1995 See abstrct	1 ~ 8
A	JP 5-171359 A(General Electric Company) 9 July 1993 See the whole document	1 ~ 8
A	US 4,803,045 A(Electric Power Research Institute, Inc.,) 7 February 1989 See the whole document	1 ~ 8

☐ Further documents are listed in the continuation of Box C.　　　☐ See patent family annex.

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"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier application or patent but published on or after the international filing date
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"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed

"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 MAY 2003 (21.05.2003)	21 MAY 2003 (21.05.2003)

Name and mailing address of the ISA/KR	Authorized officer
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